MEDINFO 98
B. Cesnik et al. (Eds)
Amsterdam: IOS Press

Extending a Teleradiology System by Tools for 3D-Visualization andVolumetric Analysis Through a Plug-in Mechanism

Harald Evers[a], Achim Mayer[a], U. Engelmann[a], Andre Schröter[a], Ulrike Baur[a], Kerstin Wolsiffer[a], Hans-Peter Meinzer[a]

[a]*Deutsches Krebsforschungszentrum, Dept. Medical and Biological Informatics, Heidelberg, Germany*

Abstract

This paper describes ongoing research concerning interactive volume visualization coupled with tools for volumetric analysis. To establish an easy to use application, the 3D-visualization has been embedded in a state of the art teleradiology system, where additional functionality is often desired beyond basic image transfer and management. Major clinical requirements for deriving spatial measures are covered by the tools, in order to realize extended diagnosis support and therapy planning. Introducing the general plug-in mechanism this work exemplarily describes the useful extension of an approved application.

Interactive visualization was achieved by a hybrid approach taking advantage of both the precise volume visualization based on the Heidelberg Raytracing Model and the graphics acceleration of modern workstations. Several tools for volumetric analysis extend the 3D-viewing. They offer 3D-pointing devices to select locations in the data volume, measure anatomical structures or control segmentation processes. A haptic interface provides a realistic perception while navigating within the 3D-reconstruction.

The work is closely related to research work in the field of heart, liver and head surgery. In cooperation with our medical partners the development of tools as presented proceed the integration of image analysis into clinical routine.

Keywords

Volume Visualization; Volumetric Analysis; Teleradiology System; Plugin-mechanism

Introduction

In teleradiology systems, communication of medical image data has been realized in combination with viewing capabilities and cooperative work. A software providing that functionality is the second generation system CHILI, which is being developed at the German Cancer Research Center in cooperation with the Steinbeis Transfer Center for Medical Informatics in Heidelberg [1]. The software design is complemented by basic research in the field of medical image analysis and volume visualization. In particular, problem-oriented studies have been successfully investigated together with radiologists and surgeons, as described e.g. in [2, 3, 4].

To integrate computer supported diagnosis or therapy planning into clinical routine, general tools for interactive segmentation and volume visualization are desirable beyond basic image transfer and management. The modules, subsequently presented, cover both aspects: On the one hand, a hybrid visualization approach is introduced on the basis of the Heidelberg Raytracing Model (HRM), which has proved to be well suited for 3D-reconstructions of medical image data [5]. On the other hand, methods for quantitative analysis have been integrated to derive volumetric measures.

Material and Methods

Plugin-mechanism

Extending the teleradiology system CHILI was established by a general plug-in mechanism. Four major aspects were emphasized within its interface description:

- The GUI-Subsystem allows users to develop modules for their own needs and to integrate them in the system's work area.
- Image data as well as additional header information can be retrieved or stored through a data interface. The communication is easily established through the light-box interface and is readily accessible for the medical user.
- Each plug-in obtains an adaptable configuration sheet to set and save persistent parameters of the module.
- Security aspects are taken into account by a certification procedure to ensure that new components follow the high security standard of the main system.

The plug-in API comes along with a styleguide providing rules to realize a consistent look and feel for the whole system. Thus, a new working task can be efficiently integrated and the medical user profits from the ergonomic design.

Hybrid Visualization

The HRM is a 3D visualization method that models the interaction of light with objects in medical data sets. It is specifically structured for the needs of medical data visualization and is the only method of its kind that incorporates shadows. This is crucial for the proper depth perception in the resulting reconstructions. Throughout the last years, the method's performance has been drastically increased by optimization of the algorithm and parallel computation [6].

In a first approach, we developed an interactive model based on the graphics standard Open GL, that allows the user to interactively navigate within the volume visualization even when the response times for 3D-reconstruction were high. The method employed, efficiently merges the volume visualizations with arbitrary surface-based graphics that can be manipulated in real time within the hybrid scene [7]. When implementing the presented plug-in for 3D-visualization the Cosmo3D™ application programming interface was used to treat complex scenes as well as to navigate in the volume data. Similar to the former approach, the surface rendering has been merged with precise volume visualization using a z-buffer approach.

A bounding box principle is used to interactively define new views on the data. Either a virtual trackball mode with the 2D-mouse or more adequate input devices (3D-mouse, 3D-pointer) with six degrees of freedom, can be connected to control the navigation of viewer in the scene. Besides, image slices are displayed simultaneously with the 3D visualization in the light box according to the position of a semitransparent plane that cuts through the volume to illustrate the correspondence.

Interactive Tools

Although a pure 3D-visualization directly supports the diagnosis in certain cases, additional functionality is desirable. Often, a quantitative evaluation of structures within the images is required in clinical routine to determines pathologic anomalies. This need can be satisfied by tools for volumetric analysis that allows mesuaring distances, angles, surfaces or subvolumes.

In the plug-in, line oriented measurements are realized by 3D-pointers. These pointers are merged with the rendered scene to achieve a good depth perception within the scene. Applying a typical 'click & draw' procedure the user select the target locations and the measure is derived and displayed. To offer volumetric information, more sophisticated methods had to be implemented. Since locating and deforming geometric shapes provide an inaccurate volumetric approximation, a segmentation oriented approach was chosen. Interactive volume growing has been integrated into the 3D-visualization to derive a more precise measurement. Because mis-segmentations might occur due to signal similarities, a interactive cutting mechanism was introduced. It permits disconnecting subvolumes at locations where a 'voxel bridge' is connecting separate areas.

Another tool for evaluating the 3D-image data in detail allows the definition of arbitrary cutting planes. By defining such planes in the scene, irrelevant information can be clipped and hidden structures can be exposed.

Force Feedback Control

Accessorily, a force feedback device can be connected to improve the tool's control. In particular, when navigating a 3D-pointer, haptic information aids in selecting desired locations in the 3D-scene. Movements are restricted to cavities and the pointing device can be pressed onto the surface of anatomical structures.

The force feedback control is closely coupled with collision detection algorithms. After tracking the current position of the 3D-device, the image volume has to be checked for a possible collision. In that case, an appropriate force reflexion is triggered to guide the navigation.

Results

A 3D-visualization module has been integrated into a state of the art teleradiology system. Using the plug-in API a framework was given to develop ergonomic tools for volumetric analysis of medical image data. The data itself was easily accessed via the light-box. We succeeded in joining two visualization techniques to one hybrid approach. Thus, a fast, interactive rendering of artificial objects, e.g. 3D-pointers, helpers for navigation or virtual instruments, has been established in combination with 3D-volume visualizations of medical image data. Specific input devices have been connected to the system to achieve a comprehensive control of the methods.

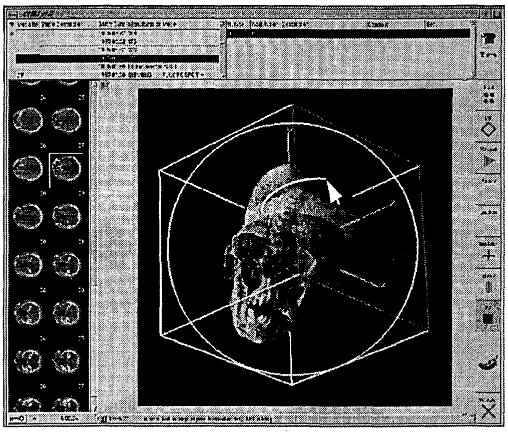

Figure 1 - Plugin for 3D-Visualization

Interactive tools for navigation and manipulation of the volumes allowed viewing of arbitrary 3D-reconstructions with extended functionality. Now, a radiologist or surgeon can evaluate them with respect to the clinical problem. Moreover, quantitative measures can be derived from the 3D-scene yielding additional spatial information for diagnosis.

First experiences with the force feedback caused positive reactions from both medical users and developers. Evidently, using that type of devices helps mapping the real world behaviour into the virtual scene. It yields an ergonomic design for controlling the view in which the data will be presented as well as appropriate tools for data manipulation.

Clinical Aspects

Several clinical scenarios take benefit from the interactive methods presented here. For the correction of septum defects in the human heart, a preoperative surgery planning is advantageous to determine the shape and dimension of a patch. Preparing the therapeutic treatment before the surgical intervention saves operation time and thus reduces the risk for the patient.

In liver surgery the location and volumetric attributes of tumours are essential for resection planning. Generally, this procedure could be applied to similar clinical problems.

Future Challenges

Techniques as demostrated within this paper are crucial for the objectives of the german research program 'Informationstechnik in der Medizin - Rechner- und sensorgestützte Chirurgie (Information technology in medicine - computer and sensor based surgery)' [8]. Beyond the navigation of the 3D-reconstruction and volumetric assessments, multi-object functionality is required for cranio-facial surgery planning [9]. After dividing the bone structure into separate sub-volumes, an independent manipulation becomes possible. As a prerequisite to simulate the correction of bone anomalies, this has to be considered in an future plug-in.

Another future aspect is the handling of time series of image data of the heart [10]. With respect to research in the field of heart surgery, segmentation methods should be interactively applied to the 4D-data to adjust the complex parameters of the tools used and shorten the evaluation time.

A challenging goal of preoperative therapy planning is the intraoperative presentation of the results. In cooperation with our medical partners this aspect will be closer investigated in the near future to proceed the integration into clinical routine.

Conclusion

Extending an existing teleradiology system through a general plug-in mechanism admits a software development dedicated to the needs of the clinical routine. Tools for 3D-visualization and volumetric analysis are essential for computer based support of diagnosis and therapy planning. Since image data can be easily accessed and investigated, a radiologist or surgeon profits from an integrated solution. Besides, applying force feedback is beneficial to provide a realistic impression and to improve the precision of the navigation.

Acknowledgements

This research was performed at the Department Medical and Biological Informatics at the German Cancer Research Center. The work is being funded by the 'Sonderforschungsbereich Informationstechnik in der Medizin - Rechner- und sensorgestützte Chirurgie' of the Deutsche Forschungsgemeinschaft.

References

[1] Engelmann U. Schröter A, Baur U, Werner O, Schwab M, Müller H, Bahner M, Meinzer HP. Second Generation Teleradiology. In: Lemke HU, Vannier MW, Inamura K (eds): Computer Assisted Radiology and Surgery. Amsterdam: Elsevier (1997) 632-637.

[2] Glombitza G, Lamadé W, Demiris AM, Goepfert MR, Richter G, Otto G, Lehnert Th, Bahner ML, Meinzer HP, Herfarth Ch. Computer Aided Planning of Liver Tumour Resection. Proc. EuroPACS 97, Pisa, Italy (1997) (in print).

[3] Makabe M, Glombitza G, Mayer A, Meinzer HP, Lederer W, Schneider W, Wrazidlo W. Interpretation Support of Contrast-Enhanced MR-Mammography by Image Processing. In: Lemke, HU, Inamura K, Jaffe CC, Vannier MW (Eds): Computer Assisted Radiology CAR'95 Berlin: Springer (1995) 254-259.

[4] Engelmann U, Makabe M, Meinzer HP. Image Procssing in Medicine: From Basic Research to Routine Clinical Use. In: Current Cancer Research 1995. Darmstadt: Steinkopf and New York: Springer 1995, 161-166.

[5] H.P. Meinzer, K. Meetz, D. Scheppelmann, U. Engelmann, H. Baur. The Heidelberg Raytracing Model. IEEE Computer Graphics & Applications. Vol 11, No. 6 (1991) 34-43.

[6] Mayer A, Makabe MH, Wolsiffer K, Niebsch R, Cardenas C, Kochner B, Baur U, Schröter A, Engelmann U, Meinzer HP. Parallele Medizinische Bildverarbeitung in Client-/Server-Umgebungen. In: Dudeck J et.al. (Hrsg.): Medizinische Informatik. Proc GI-Workshop, Klagenfurt, (1996) 73-87.

[7] Wolsiffer K, Mayer A, Niebsch R, Meinzer HP.Die Integration des Heidelberger Raytracers in OpenGL zur integrierten Segmentierung und Visualisierung dreidimensionaler medizinischer Volumendaten.In: Lehmann T et.al. (Hrsg.): Bildverarbeitung in der Medizin. Proc. des Aachener Workshops, Aachen, (1996) 143-148.

[8] Rembold U, Mühling J, Hagl S. Computer and Sensor Supported Surgery. In: Lemke HU, Vannier MW, Inamura K (eds): Computer Assisted Radiology and Surgery. Amsterdam: Elsevier (1997) 849-854.

[9] Bohner P, Holler C, Haßfeld S. Operation planning in cranio-maxillo-facial surgery. Computer Aided Surgery 2 (1997) accepted for publication

[10] Heiland M,. Makabe MH, Pearlman JD, Meinzer HP. The Cyclic Cylinder Model. A new Approach to Segment and Analyze Image Data of the Moving Heart. In: Lemke HU, Vannier MW, Inamura K (eds): Computer Assisted Radiology and Surgery. Amsterdam: Elsevier (1997) 203-208.

Address for correspondence

Harald Evers
Deutsches Krebsforschungszentrum
Div. Medical and Biological Informatics / 0805
Im Neuenheimer Feld 280
69120 Heidelberg
Tel.: +49-6221-422325
Fax.: +49-6221-422345
E-mail: h.evers@dkfz-heidelberg.de